WOCE
World Ocean Circulation Experiment

NEWSLETTER

Number 5 October 1987

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NEWS FROM THE WOCE-IPO

At the meeting of the SSG held 12-18 May at the IPO, the overall planning for WOCE was reviewed and a number of specific issues addressed. Particular attention was given to those items which need to be dealt with for the preparation of the first WOCE Implementation Plan which is to be approved by the SSG in late 1987 and published in early 1988. During the SSG meeting a half-day was devoted to the role of geochemical tracers in WOCE. Presentations were made by Jorge Sarmiento, Bill Jenkins and Dale Haidvogel. A number of scientists who were participating in a related symposium held at the Royal Society, London later the same week, also attended this session of the SSG. Special attention was given to the use of large-volume tracers which has become an issue partly because of the extra ship time required for their collection. The SSG reviewed the situation and put in place mechanisms to help resolve the remaining questions. During the same session the potential for using purposeful tracers for measuring cross-isopycnal diffusion was presented by Jim Ledwell. This technique, which is advancing rapidly, now seems certain to be a part of Core Project 3.

Special attention was also given to the progress of the WHP Planning Committee, chaired by Terry Joyce, that had held its initial meeting 27-28 April at the IPO. They had addressed a number of technical issues associated with the WHP, including specifications for certain measurements and instruments that might need to be designed or modified. They also identified a number of tasks to be carried out before their next meeting to be held at the Woods Hole Oceanographic Institute in mid-October.

The Core Project 1 Working Group, chaired by Lynne Talley and Allyn Clarke, met for the first time 4-5 June at the Scripps Institute of Oceanography. They reviewed the work that had been done since the Core Project 1 Planning Meeting, in November, 1986, which is reported elsewhere in this Newsletter, and assigned a number of tasks to members that would be needed to be completed in order to have a comprehensive plan for the Core Project ready for the WOCE Implementation Plan this autumn.

The first meeting of the Core Project 2 Working Group, chaired by Arnold Gordon, is to be held at WHOI during the week of 12-16 October. In the

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meantime the experimental plan for the Core Project is taking shape through correspondence between the working groups' members.

Responsibility for developing Core Project 3 plans beyond the ideas expressed in the Core Project 3 Planning Meeting (see WOCE Newsletter No. 4) has been given to four subgroups. Those dealing with the ocean interior and purposeful tracers met in the spring and groups dealing with the deep circulation and the surface layer will meet this autumn. Their proposals will then be reviewed by the full Core Project 3 Working Group. The first International WOCE Scientific Conference is now scheduled to be held 17-21 October 1988 at UNESCO headquarters in Paris. The main purposes of the meeting will be to review and explain the objectives and experimental plans for WOCE and to identify the contributions that nations may make for its implementation and additional resources that may be required. The primary document for discussion will be the first WOCE Implementation Plan which is presently being prepared and on which most international WOCE effort is presently being concentrated.

In order to interest oceanographers from nations that have not been closely involved in the planning of WOCE, a series of WOCE regional workshops have been planned. The first of these was held 20-22 July at the Oceanographic Institute Cidade Universitaria, Sao Paulo, Brazil at the invitation of the director, Dr Ferri. The local organizing committee was lead by Dr Y. Ikeda. An international group consisting of Mel Briscoe, Peter Killworth, Michel Lefebvre, George Needler, Lynne Talley and Walter Zenk presented the latest WOCE plans, especially as they pertain to the Oceans around South America. Oceanographers from most of the South American coastal nations outlined their oceanographic programmes. The meeting then identified a number of ways in which South America nations could participate in WOCE and sources of information and expertise that could be used in its future detailed planning.

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The Joint Oceanographic Assembly

*The Joint Oceanographic Assembly will be held in Acapulco, Mexico,
23-31 August 1988.*

Information can be obtained from
W.S. Wooster, JOA HF-05, University of Washington, Seattle WA 98195, U.S.A.
Abstracts should be submitted by 30 November, 1987 to the same address.

CORE PROJECT 1 PLANNING MEETING, WASHINGTON DC NOVEMBER 1986.

For the purpose of making the planning of a global-scale, decadal oceanographic programme somewhat more manageable, the WOCE Scientific Steering Group (SSG) has divided the problem into three overlapping “Core Project“ programmes. So-called Core Project 1 , the “Global Description” is centrally directed at the global needs of WOCE. For purposes of more clearly defining the purpose of Core Project 1, and its field implementation, the SSG convened a meeting in Washington DC, 10 - 14 November 1986, at the US National Academy of Sciences.

This meeting was attended by approximately 60 scientists plus a large number of observers. The meeting was organized by a Steering Group consisting of F. Schott, R. Heath, W. Roether, A Colin de Verdiere, A. Clarke, J. Swallow, D. Roemmich, L. Talley, Y. Nagata, H. Bryden and chaired by C. Wunsch. The Steering Group charged the meeting with producing a preliminary plan for global observations of hydrography, tracers, satellite measurements, surface fluxes, and in-situ velocity measurements which would make possible the achievement of Goal 1. The meeting was also charged with making recommendations to the SSG concerning a planning structure to carry the preliminary plan through successive refinements to an implementation plan that could be published and used world-wide to obtain the necessary resources. (In view of some misunderstandings that are current, it is especially important to realize that Core Project 1 is NOT confined to hydrography and tracers, but is directed at all measurements and ideas for which full global coverage is required.)

The overall scientific charge was paraphrased as the production of a plan which would yield a data base such that the absence of observations (e.g. of hydrography) would not be the limiting factor in determining the state of oceanic climate and dynamics. Such a goal is clearly impossible of complete achievement, but it does make a useful touchstone for planning.

Discussion of global circulation was made easier through the preparation, by members of the Steering Group, of “strawman” plans for each ocean basin prior to the meeting. This division by geography was recognized as quite arbitrary, given the global context of WOCE, and the interest in over-arching physical principles. Nonetheless, the Steering Group concluded that such a division would best facilitate discussion. To break away from purely geographical considerations, much of the subsequent discussions took place in the context of physical processes, but it was concluded that the final plan would necessarily have a strong geographical component in its description, on the purely practical grounds that ships, instruments and people are deployed in real coordinate systems.

Working Groups

Following an extended plenary discussion of how to proceed, and the relationship to the other Core Projects, particularly Core Project 2, the meeting broke up into sub-groups focused on physical processes, designed to stimulate discussion. After extended, sometimes heated, debate, the focus groups became: heat flux; boundary currents; surface fluxes, surface layer processes and water mass transformation; and the abyssal circulation.

____________________. This group focused on direct measurements of heat flux and storage, noting also the necessity of air-sea exchange measurements. Highest priority was given to a zonal section across the subtropical gyre of each ocean accompanied by shipboard acoustic doppler measurements; direct long-term measurements adequate to fully resolve the annual cycle of boundary currents in all oceans; seasonally repeated transects with XBTs using ships of opportunity; Ekman transport and variability calculations from surface wind fields, coupled with sea surface temperature estimates; measurements of the inter-ocean exchange of water using direct velocity and hydrographic tools; a focus into the North Atlantic of an effort to fully understand the temporal variability. A discussion of second and third level priority measurements as well as the specific geography of the field programme can be found in the meeting report.

Boundary Currents - chaired by Mel Briscoe. This group concluded that emphasis should be placed upon boundary current measurements at the nominal latitudes of 24°N in the Northern hemisphere, and 30°S in the Southern. Scientific discussion focused on the following questions.

* Is the curl of the wind stress related to the eastern and western boundary currents in any or all basins?
* What fraction of mass and heat crossing each of these latitudes is circulated by the boundary currents?
* Is boundary current variability reflected in the larger, basin scale circulation?
* Do boundary current measurements truly constrain general circulation models?

Three phases for observing boundary currents were defined. A first phase, necessary in some locations, is the "exploratory" one, involving satellite IR, XBTs, possibly current meters, CTDs, etc. whose purpose is to define the boundary current region adequately to carry out the second, intensive phase. This phase would involve the complete oceanographic arsenal of direct measurement tools (current meters, doppler profilers, transport floats, altimeters, etc.) to acquire enough information about horizontal, vertical, and time scales to allow the implementation of a third stage, which would be long-term monitoring with a reduced instrument inventory. The second and third stages are directed at quantitative answers to the above scientific issues. The meeting report describes in more detail what would constitute an intensive experiment, as well as providing specific geographical recommendations.

Surface Fluxes, Surface Layer Processes and Water Mass Transformation - chaired by Allyn Clarke. The group determined in this context, that the Core Project 1 should collect sufficient in-situ data in both ocean and atmospheric boundary layers to describe fluxes of heat, water and momentum across the sea surface and the response of the ocean to these fluxes, on spatial scales of 500-1000 km, on a seasonal basis. Specific goals include providing calibration for the central remotely sensed data; constraints for models on thermodynamic and dynamic response of the upper ocean; and determine upper ocean interannual variability on time scales of 5-10 years.

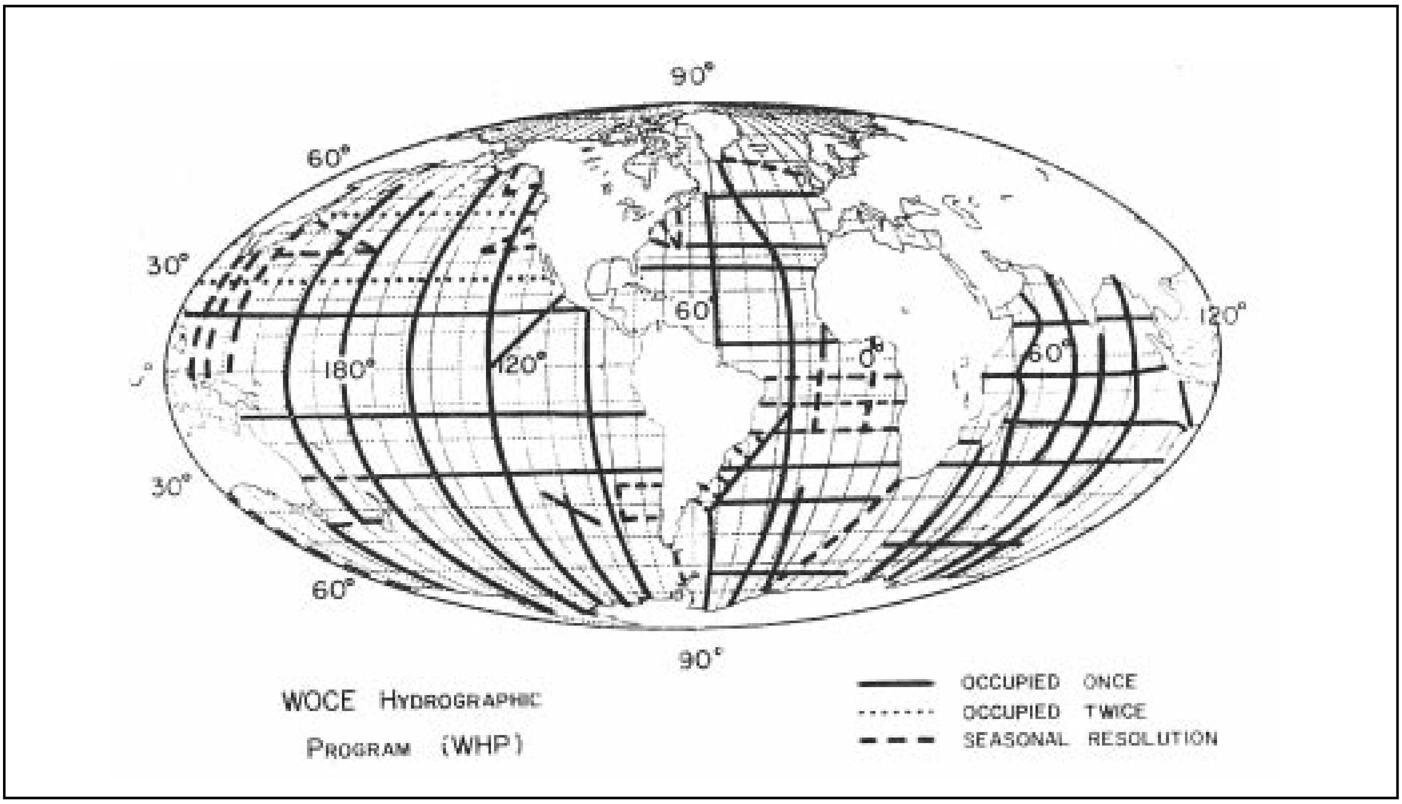
Specific recommendations were made to,

* develop operational XCTDs, and drifting/moored salinity sensors;
* combine ship, drifter and satellite measurements to estimate surface velocities on the above described time/space scales;
* develop special drifting buoys to determine sea surface temperature, air temperature, humidity, wind velocity, air pressure, and the depth dependence of temperature and salinity and to supplement these buoys with VOS and research ships;
* determine the heat, salt, and volume flux of the Arctic surface outflows in the East Greenland and Labrador Currents, of the deep overflows of the Denmark Strait and the Iceland-Faroes Channel, and of the Mediterranean over the full WOCE period;
* determine locations where the AABW fluxes of heat, salt and mass can be measured.

Abyssal Circulation - chaired by **Bruce Warren.** This group generally divided its discussion into the "interior" and the boundary currents. Specific recommendations were made for direct velocity measurements in the deep boundary currents of all oceans (not enumerated in this present brief report). For study of the interior, recommendation was made for float deployments in all oceans, preferably near 200 m, and as geographically uniform as possible (note that the Boundary Current group suggested that, initial float deployments should be primarily in western boundary currents). Some tentative suggestions for large-water volume samples in the abyss were put forward, but a detailed strategy was postponed for study by a special group.

Synthesis

At the end of the focused discussions, the meeting as a whole discussed the synthesis of the different components into a global, decadal plan. Most of the recommendations from the smaller groups were recognized as being consistent (e.g. the hydrographic programme as laid out seems to adequately serve several different purposes), but it was also realized that holes and inconsistencies inevitably remained, and would have to be dealt with in different forums.



The meeting produced a complete draft hydrographic sampling plan, a global float and current meter plan, as well as outlines for global tide gauges, XBTs, drifters etc. Full discussion may be seen in the Meeting Report which is available from the WOCE Planning Office.

Afterwards

Following the conclusion of the meeting, the WOCE SSG discussed the next steps and decided to publish the recommendations of the meeting as they stood at that time. To follow up the Core Project 1 meeting, and to move toward a detailed implementation plan, a Core Project 1 Implementation Committee was appointed under the co-chairmanship of L. Talley (Scripps), and A. Clarke (BIO). Close co-ordination with Core Project 2 planning for the Southern Ocean is anticipated.

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A LIGHTWEIGHT, FAST METHOD FOR COLLECTING LARGE-VOLUME WATER SAMPLES

The Fisheries Laboratory, Lowestoft owns 6 Hydro-Bios 436-700 “Gerard barrel” samplers which are used to collect large volume (270 1) water samples for chemical and radiochemical analysis. These were originally designed to be attached in series to a taut 12 mm diameter steel wire rope, and closed in cascade using a messenger system.

To sample at depths of up to 5500 in, we originally deployed the samplers on 7000 m of high tensile steel wire, tapering from 14 mm diameter at the winch through 13 mm to 12 mm at the outboard end. The only winch on board our research vessel CIROLANA suitable for this weight of wire was the main trawl winch, but the removal of 1800 m of tensioned 30 mm trawl warp at the beginning of each sampling cruise and the removal of the 7000 m of (now tensioned) sampler wire at the end proved to be extremely difficult and damage to both warps was inevitable. In use, the overall tension in the wire caused concern with over double the safe working load (SWL = 1/6th BS) of the wire being recorded when 5 samplers were deployed to 5000 m. The system was slow in operation, partly due to the need for cautious winchwork under these heavy loads, partly through the long messenger drop-time and partly through the inevitable pre-tripping that was encountered. In addition the designed method of handling involved overside working of the barrel to the wire preventing use except in exceptionally good weather.

After two cruises using this method, we switched to the use of plaited synthetic rope instead of wire to reduce the weight of the system and allow the use of our fishing net-drum winch and deck sheaves already used for current meter deployment. We now use spliced 500 m lengths of 18 or 20 mm diameter 8-plait ‘Nelson’ polypropylene. At the 5 sampler positions wire strops fitted with interlocked and welded egg-shaped thimbles are spliced between the rope lengths, thus producing an assembly with no sharp edges. Substituting a light system of cable and splices for the existing system of wire, shackles and shackle-bypasses was dependent on eliminating the normal 2 kg messenger as a trigger. We chose to use an acoustic triggering system based on the use of IOS Wormley CR200 acoustic release cases and transducers fitted with simplified electronics, since it involved similar operations and gear to our normal current meter mooring procedures and held out the possibility of flexible triggering of samplers (closing samplers individually or out of order etc.); after many years of deep ocean current meter work we had a small stock of outworn cases with pitted anodysing which could no longer be trusted for further 1-year current meter deployments, but would of course be perfectly satisfactory for short-term water-sampler casts. The standard pyrotechnic release device (Pyrolease) used in the CR200 was too dirty chemically and too expensive at £120 per shot for our purpose, but fortunately IOS Wormley have recently developed an alternative rechargeable retractor system for the CR200 which is clean, reliable, reusable (£20 per shot) and can be quickly recharged at sea. Though the pin-retraction is powered by a CO_2 gas cartridge, the retractor is sufficiently self-contained with O-seals to prevent release of CO_2 to the water.

The barrel triggering mechanism was therefore converted to acoustic triggering via the retractor system. The sampler lid is held open by a spring-loaded latch which is tripped by a lever when the retractor is pulled. The new system has the additional advantage that the lid is held solidly open until commanded to close so that pre-trips are impossible, with a considerable saving in station-time.

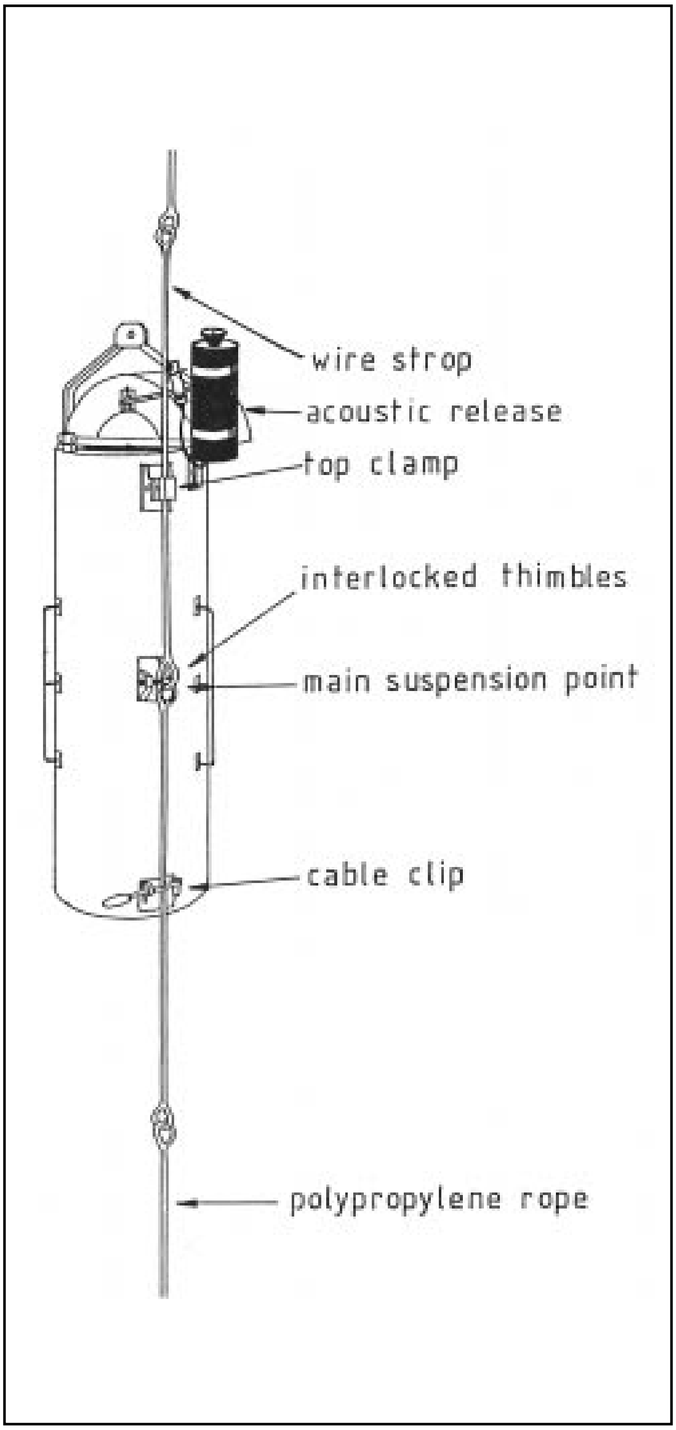
Deployment

In use the depth intervals required between samples are pre-selected and “built into” the rope by inserting the pair of 1 and 3 cm wire strops into the cable at the appropriate points. These strops are joined together round two interlocked and welded egg-shaped thimbles and terminated with another pair of similar thimbles at each end, spliced into the rope. The whole length of rope is wound onto the net drum, lead through a measuring sheave and over a derrick sheave to the ship’s side. At the end of the rope, (or possibly the bottom strop of the lowest sampler) a short wire carries an acoustic pinger and a 180 kg weight since the cable system is so light that some additional weight is needed to take the samplers down. On station the weight is lowered into the water and as the lower end of the first barrel-strop appears at rail level it is stoppered off to the rail, taking the weight of everything outboard at that point. The pair of strops can now be slacked down onto the deck and coupled to one of the rack of samplers. Of the two egg-shaped thimbles which connect the 1 and 3 m strops, the upper thimble is attached to the main sampler suspension point (see Figure) by a stainless steel pin and split pin and the upper and lower strops are then clamped to the top and bottom of the barrel by the sampler's standard retaining clips. Having attached the barrel the winch then takes the weight, the stopper is released at the rail and lowering resumes. This is repeated for each sampler and the whole string of 5 or 6 is lowered to the target depth, using the pinger bottom separation on the PDR as an indicator.

Each sampler is individually-closed on command from the ship and each one gives a positive indication of closure on the PDR. The response signal is used to confirm its acoustic height off the seabed and the simplified electronics permits each response signal to be switched off to clear the recorder for the next sample. On hauling, the samplers are detached from the wire and lifted into a cradle bolted to the rail using the ship's Hiabcrane. At no time is the main cable "broken".

Each sampler is fitted with an internal reversing thermometer assembly and an external pressure indicator (gold-plated slide) to confirm that the triggering of the sampler occurs at the correct depth. An external separate small sampler of either Niskin or Ruttner pattern collects a water sample to check the sealing of the main sampler lid. In order to allow water to be removed from the sampler without contamination from the atmosphere, a new pressure relief valve assembly was made incorporating a plastic dip tube reaching to the bottom and a new relief valve plus quick-release air pipe connector. This allowed compressed gas (nitrogen) to be used to force the water from the sampler into 50 gallon plastic drums for storage and subsequent analysis.

In summary the modified system is light, with maximum weight when the first sampler is emerging from the sea rather than when the maximum wire is out. It is quick in operation with no messenger drop-time, eliminates pre-trips, can be triggered individually or out of sequence (i.e. multiple samples can be collected at the same depth by triggering, lowering and retriggering), it gives a positive acoustic confirmation and bottom separation on the PDR, it can be used with any winch of sufficient capacity and is easily transferred from ship to ship.



Sampler suspension

Proposal

At the November 1986 Core Project 1 Workshop in Washington DC it appeared that certain regional groups were discounting the possibility of carrying out large volume sampling even though the results would be of value to their WOCE objectives, because of the long station times, the cost and/or the difficulty of using the existing system in their ships.

In the spirit of the RV WOCE programme (now the WHP) the MAFF Fisheries Laboratory, Lowestoft, offers the loan of its existing system to one or a succession of users worldwide during the WOCE observing period, since the tracer chemistry that we ourselves plan for our East Greenland programme will not involve large volume sampling.

Though some users will already be familiar with the IOS Wormley acoustic release system we are of course prepared to give tuition on our adapted large volume sampling system to any user who requests it. If the user or the WHP can assume responsibility for the cost of maintenance, round trip transport, loss or damage as part of its normal "ship expenses" all that would be needed would be a winch of sufficient cable capacity for the job in hand and some form of crane for moving full samplers (400 kg) into the rack. We can supply further details to any WOCE participating group who may be interested in borrowing this gear.

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TRANSPACIFIC SECTION AT 47°N

Introduction

Long hydrographic transects of the world's oceans with the aim of describing baroclinic flow, transports, properties and tracers on a global scale will be a basic ingredient of the WOCE Core Project 1 programme. Such sections have long been a staple of oceanographic description. Sampling philosophy has evolved in recent years to include relatively closely-spaced stations along the sections in order to minimize aliasing by mesoscale features and to adequately resolve boundary currents, sampling to the ocean bottom in order to describe flow at all levels, and employment of a CTD in addition to discrete bottles in order to fully describe the vertical temperature, salinity and oxygen structure. Inclusion of inorganic nutrient and tracer sampling at many or all stations is also a feature of many programmes. While individual transects are quite useful, a network of sections increases their value many-fold, allowing large-scale mapping and budgeting of transports and properties. Groups of sections have been occupied recently in the North and South Atlantic and in the North Pacific, with a greater or lesser degree of basin coverage: a number of these sections will be considered part of the WOCE survey.

The transect of the North Pacific subpolar gyre at 47°N in August, 1985, was one such section. The cruise track is shown in Figure 1. Both this section and a sister section at 24°N included the aspects mentioned above - relatively close station spacing, sampling to the bottom, use of a CTD, sampling for oxygen and nutrients, and a fairly large number of small-volume tracer programmes. Programmes conducted by other scientists included sampling for tritium, helium-3, chlorofluoromethanes, alkalinity, total CO_2 plutonium, carbon 14, chlorophyll, phytoplankton, and rare earth elements; an acoustic Doppler system was in operation throughout the cruise and a salt-bridge GEK was towed between stations.

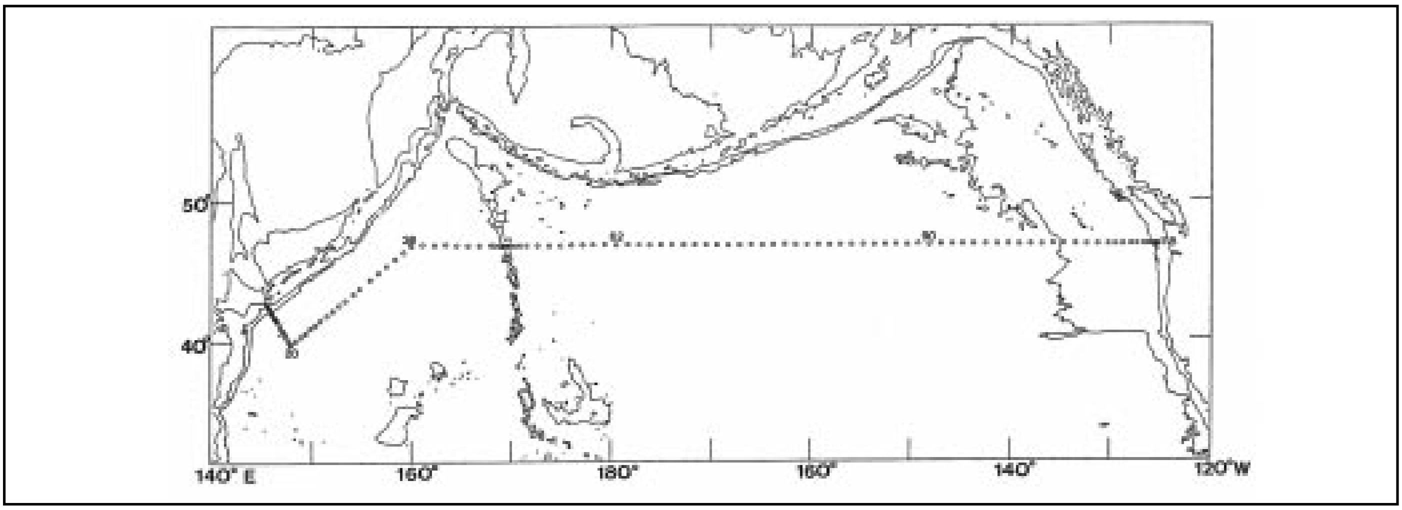

Figure 1. Stations occupied in August, 1985.

Observations

The 47°N section consisted of 115 stations to the ocean bottom; basic station spacing was 84 km with much closer spacing at the western boundary and over the Emperor Seamounts. Presented here is a sample of the observations including a description of the velocity field with simple estimates of mass and volume transports, strong evidence from CTD measurements for a basin-wide shift in curvature of the deep potential temperature/salinity relation, full confirmation of a double maximum in silicate in the eastern Pacific, and a striking zonal signal in oxygen at the oxygen minimum.

Velocities and Transports: The broad velocity pattern at the sea-surface shows northward flow over most of this subpolar section. Highest baroclinic velocities and variability are found at the western boundary, over the Emperor Seamounts, and at the eastern boundary. The western end of the section lies in the perturbed area between the Kuroshio and Oyashio; hence current and property patterns are fairly complicated there. Examination of the ten-day analyses of 100 meter temperatures produced by The Japan Meteorological Agency shows that a warm core ring was located in the centre of the westernmost leg of the transect for at least two months prior to the cruise. Water properties in the ring indicate that it was “transitional water” from the region between the Kuroshio and Oyashio. Relatively high southward velocities were found on either side of the ring, a common situation in the region: the western and eastern southwards flows have been called the first and second intrusions of the Oyashio (Kawai, 1972). Net transport in the upper waters on this westernmost leg was southward, relative to a deep reference level. For velocities at greater depths, choice of reference level or barotropic velocity is more crucial: relative to 1500 db, abyssal flow in the Japan Trench has the same sense as topographic waves, with the boundary on the right. Hence flow at the westernmost end is southward and flow on the east side in the Trench is northward. These are the same relative flow directions established using direct velocity measurements and water properties in the Aleutian Trench by Warren and Owens (1984). However, detailed examination of water properties in the Japan Trench indicated that the flow direction is actually the reverse of this. Vertical shear at all stations was of uniform sign from top to bottom, suggesting strong barotropic flow overwhelming weaker baroclinic flow which has the direction of topographic waves.

Velocity structure at the Emperor Seamounts is quite complicated: relative to 1500 db, there is northward flow on the west side and southward flow on the east side of the Seamounts. Oxygen patterns above the seamounts suggest relatively broad northward flow west and southward flow east of the Seamounts. Abyssal properties are not helpful in establishing flow direction - they merely suggest that the deepest water east of the Seamounts is older than that to the west. Abyssal properties on both sides of the Seamounts suggest much older water than that found at 35°N (Kenyon, 1983) or at the western boundary as far north as the entrance to the Bering Sea.

At the eastern boundary, flow is relatively strong and southward nearest the shore with northward flow underlying it and surfacing about 100 km offshore. Velocities are relatively strong from the boundary to the edge of the Cascadia Basin.

Between these three regions of surface flows in excess of 10 cm sec^{-1}, flow reversal which could be labelled "eddy variability" occur regularly. The magnitude of variability is larger west of about 175°E then to the east. This is apparently a transition from a western subarctic regime to an eastern one, based on all water properties as well as baroclinic velocities.

Volume and heat transports were estimated from a number of different pressure reference levels, assuming an Ekman transport of 4.5 Sverdrups southward distributed over the top 10 meters and evenly across the section. No attempt was made in this simple calculation to correct volume transports to be nearly zero or 1 Sverdrup northward. Volume transports relative to 1500 din and 7000 db were 4 Sverdrups and 5.3 Sverdrups southward respectively with a larger range of transports if other reference levels were listed. Heat transports were less sensitive to choice of reference level and varied from 0. 1 to 0.2 x 10^{15} W southward, including 0.25 x 10^{15} W southward in the Ekman layer; sensitivity to the assumed depth of the Ekman layer was somewhat greater. This estimate of heat transport and its sign agrees quite well, but perhaps fortuitously, with Talley's (1984) estimates of heat transport at 40°N and 50°S. All indicate net heat gain north of 47°N, a somewhat counterintuitive result.

The vertical distribution of volume transport relative to 1500 db and to the bottom is shown in Figure 2. The Ekman transport is southward, off-scale, and not shown. Relative to 1500 db, there is net northward geostrophic transport above 4000 db and net southward transport below. The gross structure suggested by a breakdown of these transports across the section is of a cyclonic gyre above 1500 db and an anticyclonic gyre below 1500 db. The vertical structure relative to the ocean bottom is quite different, because large jumps in deep transport relative to 1500 db are eliminated. Relative to 7000 db, most transport occurs above 2700 db, with northward transport in the topmost layer (excluding the Ekman layer), and southward in an intermediate layer. The gross horizontal structure shows the usual cyclonic gyre above 1500 db; flow in the deep water is northward in a broad region around the Emperor Seamounts and southward otherwise.

Geothermal heating: Proceeding from west to east along the transect, the curvature of the abyssal potential temperature/salinity relation shifts from negative to positive, from colder to warmer temperature at a given salinity (Joyce, et al., 1986). The change is small enough that even an ambitious bottle sampling programme would not resolve it because of scatter in salinity measurements in an

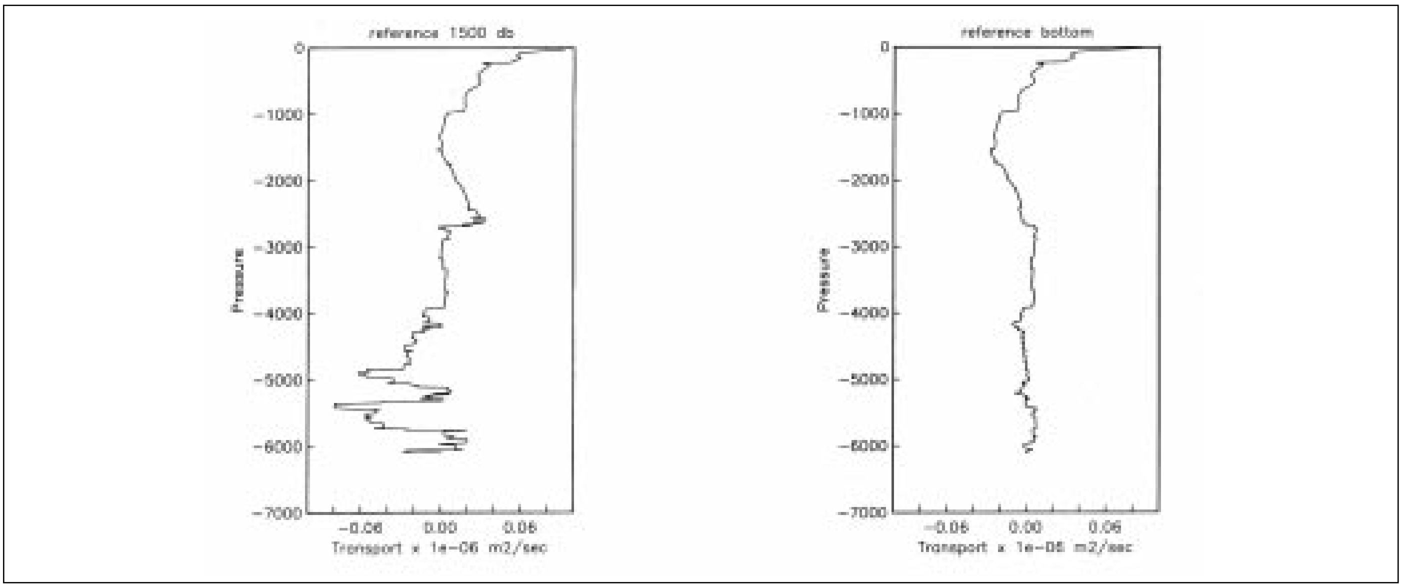

Figure 2. Vertical distribution of horizontally integrated velocities as function of pressure. Each layer 10 db thick. Total mass and heat transports are listed in the text.

environment where the maximum variation in salinity at 5000 meters is about 0.003 (ppt) along the portion of the section lying at 47°N. CTD casts however unequivocally resolve the shift in curvature, and moreover show that potential temperature increases to the east at a given salinity. Meridional sections which intersect the 47°N section indicate that the region of warmed water is isolated to latitudes between 40°N and 52°N. Because the warmed water is clearly associated with lower oxygen, hence older water, it was concluded that the potential temperature/salinity change is due to geothermal heating in the mid-ocean basins; heating rates, although low, are high enough to account for the observed change in potential temperature. A much larger change in potential temperature/salinity is observed on the 47°N section over the Cascadia Basin at the eastern end of the section, due to high geothermal activity associated with the Juan de Fuca ridge.

Silicate section: The vertical section of silicate shown in Figure 3 shows a remarkable double maxima which is highest in the east, reaching remarkable values greater than 200 (micromoles litre^{-1}) at the bottom on the deep ledge of the Cascadia Basin. It appears quite clear from this section and from maps of silicate at about 2500 meters (Reid, 1981) that the eastern boundary is the primary source of high silicate in the mid-depth maximum in the eastern Pacific. The Bering Sea is also a source of high silicate at about the same depth and density, and is probably the source of the isolated maximum centred at station 38.

The bottom maximum has not been as evident from previous data: the section at 47°N and a meridional section at 152°W indicate that bottom values increase dramatically to the east and that the maximum is coincided to latitudes between 40°N and 53°N. This region coincides with that in which older water was identified on the basis of deep potential temperature/salinity curvature and an hypothesis of geothermal heating. It is clear from the 47°N section that the source of high silicate is the ocean bottom in the east up to the Cascadia Basin. Because the bottom maximum crosses isopycnals to the west, it is not clear how much of the signal is advective and how much is local. Toward the Emperor Seamounts, the maximum does lift slightly off the bottom.

Other noteworthy features of the silicate section are the high values in the Japan Trench which, along with signals of all other water properties, indicate a southern source of abyssal waters. The dip in silicate from the surface to about 1500 meters between stations 7 and 18 is also mirrored in all other properties and indicates subtropical influence between the first and second Oyashio intrusion, as remarked in the section on velocities.

Oxygen, phosphate and nitrate: These vertical sections are not shown, but have well-known extrema at about 1000 meters. Examination of these three properties along their extrema (minimum in oxygen and maxima in phosphate and nitrate) and along isopycnals which intersect the extrema shows a zonal pattern which must reflect the gyre circulation and sources of the nutrients. Referring only to oxygen since all three show similar patterns, oxygen is highest in the very west where subtropical influence is strong and in a wide region east of 170°W. Between stations

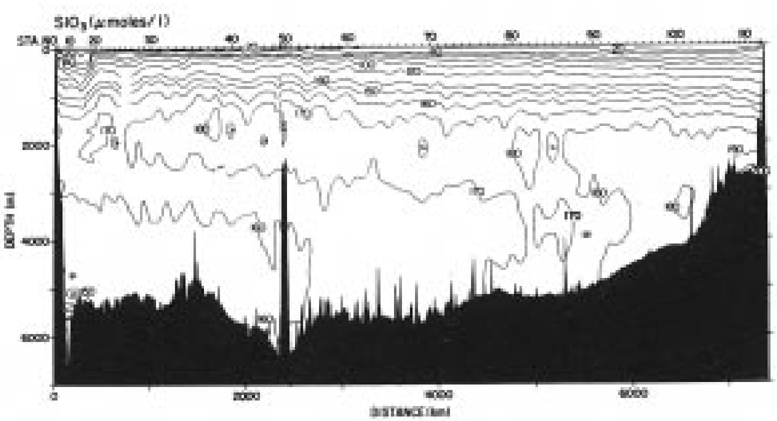

Figure 3. Vertical section of silicates

25 and 70, oxygen is 0.2 to 0.3 (micromoles litre^{-1}) lower at the minimum. The conclusion is that subtropical influence is stronger in the east than in the west whether due to a northward swing of the windstress pattern, hence closer proximity to the subtropical gyre, to the east, or due to a greater admixture of subtropical waters in the east.

Within this broad pattern, a finer pattern near the Emperors shows higher oxygen west of the Seamounts and lower oxygen east of the Seamounts, perhaps indicating northward and southward flow respectively.

Conclusions

The relatively fine-scale survey at 47°N show a number of new features, some of which would have been barely detectable without a CTD and others of which simply required a good survey of water properties in the region. Use of other high-quality sections in conjunction with this subpolar transect should allow basin-wide budgets of heat and mass and basin-wide mapping of properties and circulation. Such studies are currently being pursued by a number of investigators associated with these sections.

References

Joyce, T.M., B.A. Warren and L.D. Talley, 1986. The geothermal heating of the abyssal subarctic Pacific Ocean. Deep-Sea Res.. 33, 1003-1015.

Kawai, R, 1972. Hydrography of the Kuroshio Extension. In Kuroshio, ed. Stommel and Yoshida, 235-352.

Kenyon, K.E., 1983. Sections along 35°N in the Pacific. Deep-Sea Res.. 30, 349-370.

Reid, J.L., 1981. On the mid-depth circulation of the world ocean. In Evolution of Physical Oceanography, ed. B.A. Warren and C. Wunsch, 70-111.

Talley, L.D., 1984. Meridional heat transport in the Pacific Ocean. J. Phys. Oceanogr.. 14, 231-241.

Warren, B.A. and W.B. Owens, 1984. Some preliminary results concerning deep northern-boundary currents in the North Pacific. Prog. Oceanogr., 14, 537-551.

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DRIFTING BUOY DATA FOR MARINE RESEARCH

Introduction

With the advent during the early 1970s of the ability to track by satellite the movements of radio transmitters on or above the earth’s surface, many limitations imposed by traditional tracking techniques on the use of drifting buoys to study ocean currents were eliminated. With subsequent improvements in buoy system capabilities, buoys are not providing a cost-effective means of obtaining long-term, in-situ measurement of environmental parameters from vast and remote ocean areas. A comprehensive archive of past and present drifting buoy data is needed to improve their availability and usefulness for studies of large-scale circulation and climatology such as WOCE and TOGA. Unfortunately, opportunities to preserve these data are being lost.

The purposes of this article are to note the potential importance of these data to present and future research efforts, to describe the coordinated efforts of the Canadian Marine Environmental Data Service (MEDS) and the US National Oceanographic Data Center (NODC) to assemble a comprehensive archive of these data, and to stimulate increased flow of data to the archives. Furthermore, it is hoped that this article will promote a more vigorous dialogue between WOCE researchers and archive centres, so that data management issues will be addressed in a way that will help ensure a successful WOCE.

The Value of Data from Drifting Buoys

Surface drifting buoys have been most frequently used to measure surface currents, sea surface temperature, and sea level pressure. Surface currents (or, if the buoy is drogued, currents at drogue depth) are inferred from the buoy trajectory. Other parameters which have occasionally been measured with varying degrees of success include air temperature, wind velocity, air pressure variation, wave characteristics, subsurface temperatures, subsurface relative currents, and ambient noise (to infer wind speed and precipitation). Possible future sensors include those for atmospheric humidity, incoming shortwave and outgoing longwave radiation, acoustic bottom sounding, and acoustic Doppler current profiling.

In addition to their unique capability to provide a (quasi-) Lagrangian description of ocean circulation and to fill voids in coverage afforded by ship observations, buoy observations also complement those made by satellites by providing some information which satellites cannot (e.g., air temperature and subsurface parameters) and by providing independent "surface truth" data for comparison with remotely-sensed fields. Such comparisons are necessary because

* remotely-sensed fields are derived using empirical algorithms whose limitations over widely varying environmental conditions are not fully understood (US WOCE Science Steering Committee, 1986),
* like other sensors, satellite sensors can experience calibration drift,
* estimates of air-sea fluxes which are important to climate studies are sensitive to errors in the observed fields, making it essential that these fields be as accurate as possible.

Another important consideration in climate studies is that historical data may provide a baseline against which future observations can be evaluated. Although drifting buoy data are valuable, they are not free of problems. There is still debate over water-following abilities of buoys and quality of sensor data. Attempts to improve the water-following properties by using drogues have been complicated by the short lifetime of the drogue relative to the buoy's radio transmitter. Detection of calibration drifts or subtle systematic errors in sensor data requires independent observations which are rare. In retrospective studies, uncertainties about data quality are often exacerbated by a lack of adequate documentation on hull design, deployment configuration (drogue type, depth, etc.) and calibration information (World Climate Research Programme, 1985).

Current Status of the Archives

There is a well developed international system of oceanographic data management which falls within the context of the Intergovernmental Oceanographic Commission (IOC). The system is based on a hierarchy of data centres beginning at national centres within a country, to responsible centres specializing in particular data, to world data centres to coordinate exchange of data internationally. All of these agencies work closely together to coordinate the flow of data to world centres and thereby to international users of the data.

NODC in Washington operates one of the world data centres for the IOC. In this role, they receive data from other data centres and exchange them internationally. At the next level, MEDS was recently accredited a Responsible National Oceanographic Data Centre (RNODC) for drifting buoy data. MEDS (Keeley and Taylor, 1982) began its activities with these data in the FGGE programme in 1978 by archiving all drifting buoy data reporting over the Global Telecommunications System (GTS). From 1980 until the summer of 1986, only those buoys reporting from waters surrounding Canada (35°-90°N, 40°-180°W) were archived. Since receiving accreditation as the RNODC, MEDS has again been receiving and archiving all drifting buoy data transmitted over GTS.

Finally, at the lowest level, both MEDS and NODC act as national data centres for all oceanographic data collected in their regions of interest. With respect to drifting buoy data, NODC does not monitor GTS, but receives data in a delayed mode directly from principal investigators. Their current holdings contain reports from over 700 buoys and the number is growing because of the TOGA project. NODC holdings come from all over the world and begin in 1974.

MEDS and NODC will be cooperating to assemble as comprehensive an archive of quality-controlled drifting buoy data in the RNODC as is possible. It is estimated that the combined holdings of these two centres account for less than half of the data that have been, and are now being, collected. Based on its own holdings and a review of published literature, NODC estimated that more than 1400 surface trajectories have been obtained historically world-wide. As recently as December 1986, only 195 of 395 drifting buoys being tracked by Service ARGOS were being entered into GTS.

Data Submission to the Archives

There are three paths by which drifting buoy data can reach the RNODC. The traditional path for data entering the archive is by submission from the principal investigator to his national centre (in the US this is required for most federally funded projects). Copies can then be forwarded to the RNODC. These data are presumably of the highest quality since they have been subjected to the most discriminating quality control procedures. However, it is typical that long delays occur between data collection and submission to an archive. Also, non-uniformity of processing techniques employed by different investigators may pose problems for secondary data users who wish to combine data sets. This highlights the need for adequate supporting documentation accompanying each data set submitted to the archive. Unfortunately, such documentation is often not provided.

A second path for data flow to the archive is via the GTS. An advantage of this path is that data are available in real time to operational users such as forecasters and TOGA researchers. A second advantage is that the RNODC currently has a well developed processing system for GTS data.

One impediment to the flow of data along this path is the requirement that data be transmitted from the buoy in a format specified by Service ARGOS (WMO, 1983). Then the data must be converted to a second format specified by the World Meteorological Organization (WMO) before it can be entered into GTS. For some buoy transmissions, such as thermistor chain observations, software is not yet available at Service ARGOS to perform the format conversion (WMO/IOC, 1986). Once data are in the proper format and administrative procedures to initiate data flow have been completed, data can be injected into the GTS at no charge to the originator. Other impediments to data entry into the GTS include reluctance of the principal investigator to allow his data to be entered or a lack of awareness of the GTS option. Reluctance may be due to concern about possible earlier publication of data analyses by opportunists, concern that the relatively raw data flowing in GTS may be of insufficient quality for archival, or a perception that administrative procedures required to initiate automatic entry into GTS are too inconvenient (Committee on Climatic Changes and the Ocean, 1986). Certainly most of these impediments could be reduced with some effort. In particular, mutually agreeable arrangements can be negotiated between the archive and principal investigators with regard to a period during which data would be held proprietary. Also, the GTS version of data can be distinguished from, or replaced by, the version supplied in a delayed mode by the principal investigator.

However, even with full participation, there are disadvantages to the GTS pathway. Some observed parameters cannot be accommodated within, or must be reduced in precision to fit into, the GTS standard format. Also, supporting documentation such as buoy hull type, sensor calibration information, project, principal investigator, etc., is not transmitted over GTS, and if it is to be preserved, must be forwarded to the archive by the principal investigator.

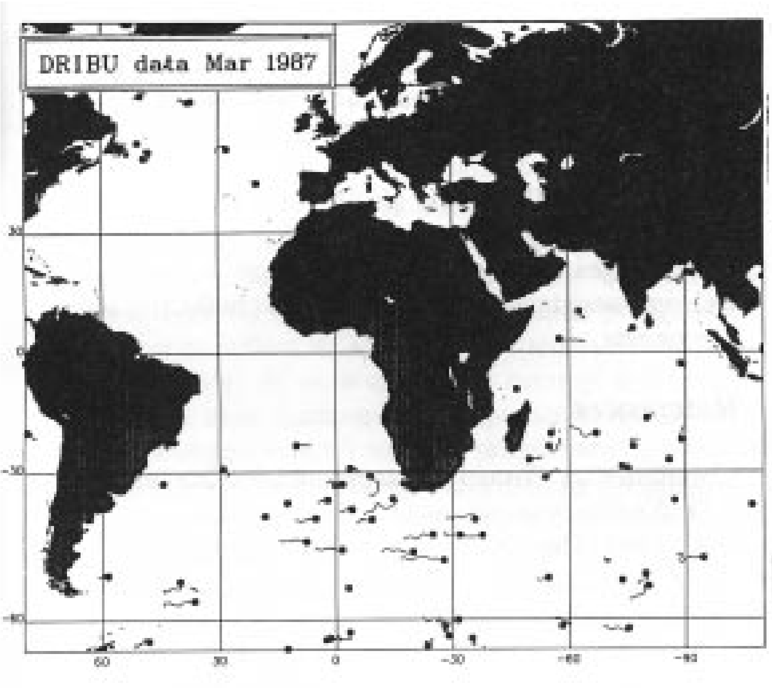
The third way by which data can reach the RNODC is on tape from Service ARGOS, with the written permission from the principal investigator. An advantage of this option is that the data would contain a complete set of parameters at the full precision provided by the ARGOS system. A disadvantage is that data formats are likely to vary among projects. Each principal investigator would have to provide the RNODC with a description of his format and, in some cases, decoding algorithms. At the same time he should submit all relevant supporting documentation.

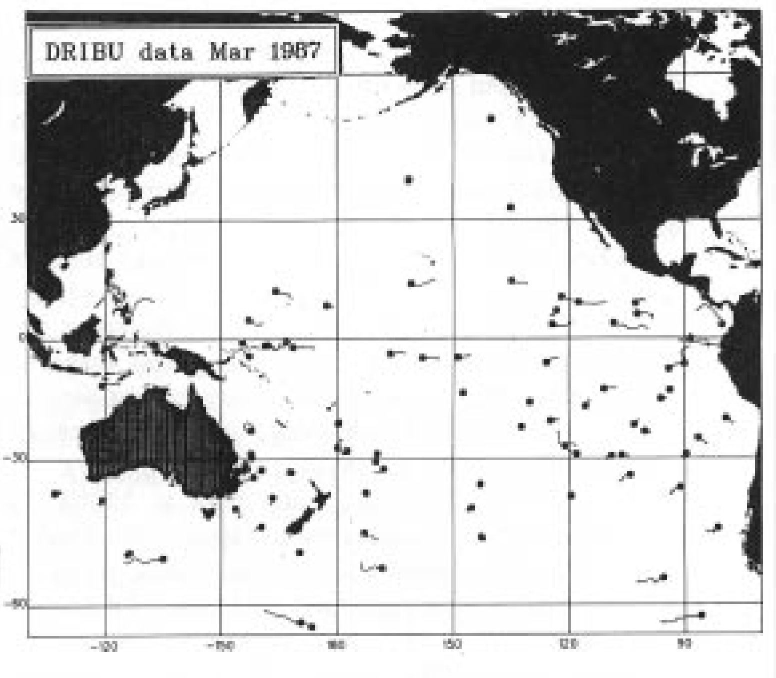
Quality Control Procedures

Data centres have a fundamental responsibility to preserve the integrity of original data while striving to improve the quality of data in the archive. To ensure high quality, it has been argued that only data of known and acceptable accuracies be admitted (Committee on Climatic Changes and the Ocean, 1986). By implementing this, an archive would exclude data that others consider of value even with their acknowledged deficiencies. An archive must attempt to satisfy both interests. To this end data centres carry out cheeks to identify “impossible” values in data they receive. These are then either deleted or corrected. Other data seem “questionable”, that is, having values within established limits but suspect within the context of other data. At MEDS such values are flagged, leaving final judgement to secondary data users.

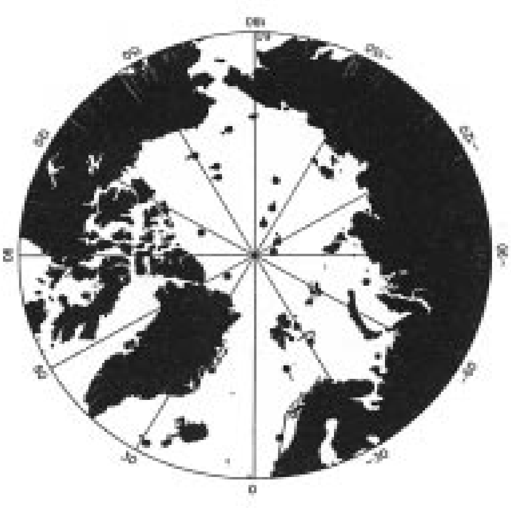
Archive Services

The RNODC maintains its drifting buoy data in a computerized database structure. This provides maximum flexibility when meeting a request. While a number of different qualifiers may be used to retrieve

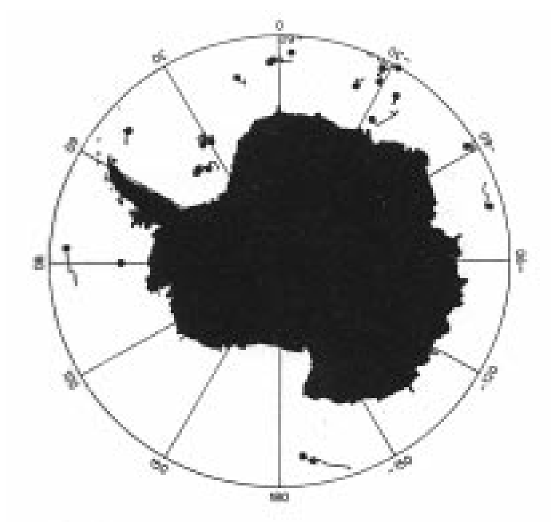




DRIBU data Mar 1987



DRIBU data Mar 1987



"Tracks of Drifting Buoys Reporting over the GTS".

data, the most common are area and time. It is possible to select only data which have passed quality checks. Output is written to magnetic tape in a standard GF3 format (IOC, 1980). The RNODC will also send requesters data of interest and associated format information copied from that provided by Service ARGOS.

MEDS publishes a monthly summary of data received in real time. As an extension to this activity and as the first expansion of services offered as the RNODC, MEDS is now producing global maps of drifting buoy tracks (see Figure). Anyone wishing to receive this monthly summary, which is free of charge, should notify MEDS.

The archive of drifting buoy data at NODC is maintained off-line on magnetic tapes. To expedite various data management operations, NODC prefers to receive data in a defined standard format. Of course, data which do not conform to the standard format are accepted, but until they are converted, they can only be made available as tape copies in the originator's format.

Recommendations

The value of an archive is proportional to the quantity and quality of data which it can make available to secondary users. This paper has presented a brief description of how drifting buoy data are currently managed by MEDS and NODC and has identified some of the strengths and weaknesses of the current mechanisms for entering data into the archives. Some ways to increase the flow of data to the archives are readily apparent. First, we need to continue to encourage holders of historical drifting buoy data to contact their national data centre or the RNODC and make the necessary arrangements for submitting them. Those who currently have operating buoys, or who are planning future buoy deployments, are encouraged to contact Service ARGOS to determine whether the data being transmitted are suitable for the GTS. Also, they are encouraged to authorize Service ARGOS to forward their data on tape to MEDS and provide all necessary information to translate the data. Finally, the principal investigator should follow through with submission of his processed data to his national centre once he is satisfied with the quality. In all cases, the principal investigator should assure that data submitted are accompanied by adequate documentation to allow for informed evaluation by secondary data users. Concerns about the proprietary status of data can be discussed at any appropriate time with the centre to which the data are submitted. Data are of value only when they are available for analyses. Efforts are increasing at MEDS and NODC to provide drifting buoy data management services that are useful to WOCE researchers and others, however we need and welcome assistance and suggestions from the research community.

References

Committee on Climatic Changes and the Ocean, 1986, Drifting buoy questionnaire, 16 June 1986.

IOC, 1980, The IOC general magnetic tape format for the international exchange of oceanographic data, Manuals and Guides No. 9.

Keeley, J.R. and J.D. Taylor, 1982, FGGE atlas of sea surface temperature and drifting buoy tracks, Deep Sea Research, 29(5A),659-661.

US WOCE Science Steering Committee, 1986, Status report on US WOCE planning, US WOCE Planning Report, No. 3, 229pp.

WMO, 1983, Guide to data collection services using Service ARGOS, Marine meteorology and related oceanographic activities, Report No. 10.

WMO/IOC, 1986, Final report, Meeting on ARGOS joint tariff agreement, Sixth meeting, Geneva, 20-22 October 1986.

World Climate Research Programme, 1985, Report of the TOGA drifters planning meeting, La Jolla, USA, 27-29 March, 1985, WCP-103.

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FIRST SOUTH AFRICAN WOCE WORKSHOP

The planning of national contributions to WOCE, the World Ocean Circulation Experiment, are far advanced in a few countries, less so in most others. As recognised by the WOCE IPO, national programmes are apt to reflect to a degree the research needs and requirements of each respective country and thus to differ in their contents. The manner in which each contributing country's research programme is planned may to some extent reflect these different perceptions of their needs. 1 present here a report of the first South African WOCE Workshop, held on 21 and 22 October 1986 at the National Research Institute for Oceanology at Stellenbosch, which may be of more general interest since it represents a component of the planning by a small country.

Large research programmes in South Africa, which are perceived as addressing a national need and which would by their nature involve more than one individual scientist or group, are after some deliberation usually recognised as National Programmes funded and managed by the Foundation for Research Development of the Council for Scientific and Industrial Research (CSIR). This agency is in practice closely akin to the National Science Foundation in the USA. Such National Programmes include amongst others Pollution, Oceanography, Weather, Climate and Atmospheric Research as well as Remote Sensing. The initiative to start considering a South African WOCE effort came from scientists and co-ordinators within the Oceanography, Weather-Climate-Atmospheric Research and Antarctic National Programmes. An ad hoc WOCE planning committee, representing these National Programmes, universities, research institutes and the Weather Bureau, was formed early in 1986. Its terms of reference were to establish whether there exists a need for a South African WOCE and to advise on its most logical place within already established National Programmes. After only two meetings general consensus was reached that a South African WOCE programme should be established and that it should report to the Oceanography, the Climate and the Antarctic programmes but be funded and managed within the Oceanography programme. The requirement to report to the Antarctic programme arises from the fact that this programme has a well-developed Southern Ocean research component. The ad hoc WOCE planning committee also suggested that a WOCE Workshop be held to establish the research framework, key questions and aims of a South African WOCE. The rest of this report sets out some of the thoughts expressed at this workshop which included most deep-sea oceanographers in South Africa.

Although it was accepted at the WOCE workshop that the programme would have to operate within present budgetary and manpower restraints, it was recognised that South Africa, because of its unique geographic location was nonetheless in a position to make some major contributions to the overall aims of WOCE by concentrating particularly on those research areas which are logistically easily accessible. Professor Tyson from the Climatological Research Group at the University of the Witwatersrand stressed the importance of a more detailed knowledge of certain oceanic circulation patterns on the climate of the Southern African subcontinent. Three rather arbitrary ocean areas were selected, namely the Southwest Indian Ocean, the Southeast Atlantic Ocean and the Southern Ocean sector south of Africa, in which to identify particularly striking gaps in our knowledge and to establish which of these required concerted research efforts in a South African WOCE.

As far as the Southwest Indian Ocean is concerned, it was recognised that the relationship between the ocean-wide wind stress and variations in the current fluxes is poorly understood. The tributaries to the Agulhas Current and their variations are not known. A better understanding of the quantities and the mechanisms by which exchange of water between the Indian and the Atlantic Oceans takes place was considered as a prime aim of the programme. All aspects of the mass, heat and salt flux of the Agulhas Current and its constituent parts should also receive high priority, including heat flux to the overlying atmosphere, The possible influence of sea surface temperature anomalies on the weather patterns over Southern Africa was also highlighted as an important research project.

With the exception of the coastal and the southern upwelling cells, (particularly the latter), very little is known about the meso to macroscale circulation patterns in the Southeast Atlantic Ocean. A study of the penetration of Agulhas water into this ocean by way of Agulhas Rings was considered to be of prime importance since it is believed that the influence of these features may be much more extensive than suggested heretofore. The two generic borders to this ocean area, namely the Angolan front to the north and the Subtropical Convergence to the south are very poorly understood. In the case of the Subtropical Convergence, it has been noted that significant leakages of Subantarctic Surface Water into the South Atlantic, especially adjacent to the Agulhas Retroflection, may be an important mechanism for poleward heat transport. In the South Atlantic the Walvis Ridge forms a nearly impenetrable border to the northward flow of Antarctic Bottom Water. Leakage of water at a few breaks in the ridge and the variability in volume of these leaks may have important climatologic connotations.

Water transformation at high latitudes has always been recognised as an important climatological factor. Two mechanisms of water mass formation take place in the Southeast Atlantic Ocean. Neither has received much research attention. Warm Indian Ocean surface water entering the area by way of the Agulhas Rings rapidly cool and is believed to sink and to ventilate the thermocline. Vast amounts of South Atlantic Central Water upwell at the wind-induced coastal upwelling cells where streamers and filaments introduce this rapidly warming water into the upper layers of a considerable part of this ocean area. The quantities of water involved in these processes and any seasonal and/or interannual variations in this flux are unknown and should be addressed.

Although our knowledge on the geographic location and the mesoscale characteristics of the fronts in the Southern Ocean south of Africa has increased in the last decade, our understanding of their mesoscale behaviour has not. By using SEASAT altimetry it has come to be recognised that certain specific parts of the circulation exhibit greatly enhanced levels of mesoscale variability. It has been suggested that these areas may represent preferred conducts for meridional heat transport into the Southern Ocean which require intensive investigation. The most extensive and intense such “hot spot” area is located south of Africa. The mesoscale kinematics of all the oceanic fronts, the Subtropical Convergence, the Subantarctic Front as well as the Antarctic Polar Front require further study, Monitoring of the flux of the Antarctic Circumpolar Current by regular lines of hydrographic stations between South Africa and Antarctica has been suggested as well as placing sea-level gauges at Antarctica, Bouvet Island, Marion Island and Gough Island to study the barotropic signal. Establishing the location of abyssal boundary currents by which Antarctic Bottom Water penetrates into the Subtropical basins was also considered worthy of further investigations.

Having identified the gaps in our knowledge on the circulation patterns in the oceans bordering South Africa and having established which would be amenable to study from South Africa, a draft National Programme is being drawn up to act as a framework for research efforts in the 1990s. It was, however, also clear from discussions that a number of cruises and other investigations are already underway or planned which address some of the research problems set out above. A good foundation is thus already being laid well before 1990.

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WOCE is a component of the World Climate Research Programme (WCRP), which was established by WMO and ICSU, and is carried out in association with IOC and SCOR. The scientific planning and development of WOCE is under the guidance of the ISC/CCCO Scientific Steering Group for WOCE, assisted by the International WOCE Planning Office. JSC and CCCO are the main bodies of WMO-ICSU and IOC-SCOR, respectively for formulating overall WCRP scientific concepts.

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Contributions should not be cited without the agreement of the author.

We hope that colleagues will see this Newsletter as a means of reporting work in progress related to the Goals of WOCE as described in the Scientific Plan. The SSG will use it also to report progress of working groups, and of experiment design and of models.

The editor will be pleased to send copies of the Newsletter to Institutes and Research Scientists with an interest in WOCE or related research.